

General Marking Instructions

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A [15 marks] and all questions from **ONE** option in Section B [20 marks].
Maximum total = [35 marks].

Markscheme format example:

Question		Answers	Notes		Total
4.	b ii	the displacement and acceleration ✓ are in opposite directions ✓	<i>Accept force for acceleration.</i>		2

- Each row in the “Question” column relates to the smallest subpart of the question.
- The maximum mark for each question subpart is indicated in the “Total” column.
- Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
- A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
- An alternative wording is indicated in the “Answers” column by a slash (/). Either wording can be accepted.
- An alternative answer is indicated in the “Answers” column by “**OR**” on the line between the alternatives. Either answer can be accepted.
- Words in angled brackets < > in the “Answers” column are not necessary to gain the mark.
- Words that are underlined are essential for the mark.
- The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
- If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the “Notes” column.
- Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. “ECF acceptable” will be displayed in the “Notes” column.
13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.

SECTION A

Question		Answers	Notes	Total
1.	a	$a = 330 \text{ } \langle \text{m s}^{-1} \rangle \checkmark$		1
	a	$b_{\text{max}} = \left\langle \frac{344 - 316}{40} \right\rangle = 0.70 \text{ } \langle \text{m s}^{-1} \text{ } ^\circ\text{C}^{-1} \rangle \checkmark$ $b_{\text{min}} = \left\langle \frac{340 - 318}{40} \right\rangle = 0.55 \text{ } \langle \text{m s}^{-1} \text{ } ^\circ\text{C}^{-1} \rangle \checkmark$ $\Delta b = \left\langle \frac{0.70 - 0.55}{2} \right\rangle = 0.075 \approx 0.08 \text{ } \langle \text{m s}^{-1} \text{ } ^\circ\text{C}^{-1} \rangle \checkmark$		3
	a	$b = 0.59 (\pm 0.08) \text{ } \langle \text{m s}^{-1} \text{ } ^\circ\text{C}^{-1} \rangle \checkmark$	<i>Allow 0.593 (± 0.075).</i>	1
	b	$\theta = \left\langle \frac{-330}{0.6} \right\rangle = -550 \text{ } \langle ^\circ\text{C} \rangle \checkmark$		1
	b	temperature is unphysical OR there is no temperature below -273°C OR this temperature cannot be right \checkmark it appears that the linear fit model cannot be extrapolated far from 0°C \checkmark		2

Question		Answers	Notes	Total
2.	a	the estimated percentage uncertainty in g is $2 \times 0.3 + 0.6 = 1\%$ ✓	Accept 1.2 %.	1
	b	<p>use more than one height ✓</p> <p>obtain g from a suitable graph of height h versus t^2 ✓</p> <p>g is twice the gradient ✓</p> <p>OR</p> <p>use a smaller ball (to reduce air resistance) ✓</p> <p>use a (much) larger height ✓</p> <p>repeat many times (to get an average of time) ✓</p>	<p>Allow h versus t^2 or \sqrt{h} versus t or $\log h$ log t.</p> <p>Analysis of g must fit quoted graph.</p>	3

3.	a	<p>the actual specific heat capacity will be less than calculated value ✓</p> <p>more thermal energy is transferred to the calorimeter and contents than accounted for ✓</p>	Do not allow a bald answer.	2
	b	<p>metal may not have been heated uniformly</p> <p>OR</p> <p>metal may not all be at 100°C ✓</p> <p>energy was lost to air during the transfer ✓</p> <p>energy may have been lost to the air through the calorimeter ✓</p> <p>water may not be at uniform temperature ✓</p>		1 max

SECTION B

Option A — Relativity

Question		Answers	Notes	Total
4.	a	Maxwell's equations implied a speed of light independent of its source <i>OR</i> in Newtonian mechanics, speed of light depends on velocity of source ✓ Einstein trusted Maxwell's equations <i>OR</i> Einstein modified Newtonian mechanics ✓		2
	b	i magnetic ✓		1
	b	ii if a force exists in one ⟨inertial⟩ frame a force must exist in any other ⟨inertial⟩ frame ✓ cannot be magnetic because the proton is at rest in S' ✓	Accept discussion in terms of acceleration as equivalent to force. Accept an answer in terms of electric field.	2

5.	a	i $\langle \frac{900}{c} \rangle = 3.0 \times 10^{-6} \langle s \rangle$ ✓		1
	a	ii $\gamma = \langle \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \rangle = \frac{1}{\sqrt{1 - 0.64}} = \frac{5}{3} \approx 1.67$ ✓ $\Delta t = \langle \gamma \left[\Delta t' + \frac{v \Delta x'}{c^2} \right] \rangle = \frac{5}{3} \left[3.0 \times 10^{-6} + \frac{0.80c \times 900}{c^2} \right]$ ✓ $= 9.0 \times 10^{-6} \langle s \rangle$ ✓		3

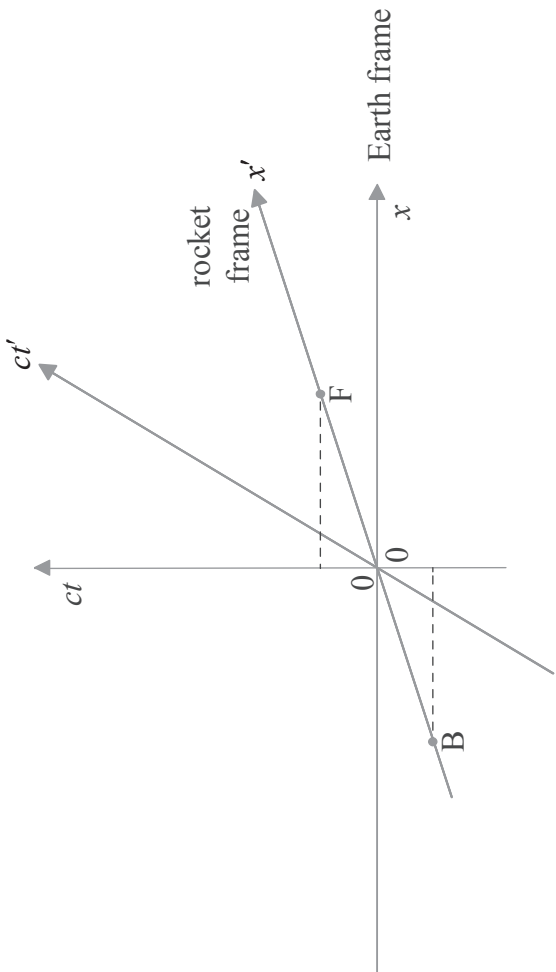
(continued...)

(Question 5 continued)

Question		Answers	Notes	Total
a	iii	$\Delta x = \Delta ct = 3.0 \times 10^8 \times 9.0 \times 10^{-6} \Rightarrow 2700 \text{ m}$ OR $\Delta x = \gamma [\Delta x' + v \Delta t'] = \frac{5}{3} \left[900 + 0.80c \times \frac{900}{c} \right] \Rightarrow 2700 \text{ m}$ ✓		1
	b	i <p>starting points at B and F ✓ ending at the same point on the ct' axis ✓ correct slope at 45° degrees ✓</p>	<i>Judge by eye.</i>	3

(continued...)

(Question 5 continued)

Question	Answers	Notes	Total
b ii	 <p>lines through B and F parallel to x-axis ✓ to see that B happened first ✓</p>		2
b iii	$\Delta t = \gamma \left[\Delta t' + \frac{v \Delta x'}{c^2} \right] \Rightarrow \frac{5}{3} \left[0 + \frac{0.80c \times [900]}{c^2} \right] \checkmark$ $\Delta t = 4.0 \times 10^{-6} \text{ s} \checkmark$		
c	solving for u ✓ correct substitution ✓ correct answer of 0.36c ✓		3

Option B — Engineering physics

Question		Answers	Notes	Total
6.	a	$\alpha = \frac{a}{R} \checkmark$ $T \times R = \frac{1}{2} MR^2 \frac{a}{R} \checkmark$ $mg - T = ma \checkmark$ <p>⟨add equations/eliminate tension⟩ to get $mg = ma + \frac{1}{2} Ma \checkmark$</p>		4
	b	$a = \left\langle \frac{24 \times 9.8}{36} \right\rangle = 5.6 \langle \text{m s}^{-2} \rangle \checkmark$ $v = \left\langle \sqrt{2as} \right\rangle = \sqrt{2 \times 5.6 \times 16} = 13.4 \approx 13 \langle \text{m s}^{-1} \rangle \checkmark$ <p>OR</p> $mgh = \frac{1}{2} mv^2 + \frac{1}{2} I^2 \omega^2$ <p>OR</p> $mgh = \frac{1}{2} mv^2 + \frac{1}{2} I \frac{v^2}{R^2} \checkmark$ $v = \left\langle \sqrt{\frac{2 \times 24 \times 9.8 \times 16}{24 + 18}} \right\rangle = 13.4 \approx 13 \langle \text{m s}^{-1} \rangle \checkmark$	Award [2] for a bald correct answer.	2

(continued...)

(Question 6 continued)

Question	Answers	Notes	Total
b ii	<p>rate of change of L is $I\alpha = I \frac{a}{R}$ ✓</p> $\left\langle \frac{1}{2} MR^2 \frac{a}{R} \right\rangle = \frac{1}{2} \times 36 \times 0.20 \times \frac{24 \times 9.8}{24 + \frac{36}{2}}$ $= 20.2 \approx 20 \langle \text{N m} \rangle$ ✓ <p>OR</p> <p>rate of change of L is Γ (torque on axle) ✓</p> $\Gamma = TR = \frac{1}{2} \times 36 \times \frac{24 \times 9.8}{24 + \frac{36}{2}} \times 0.20$ ✓ $= 20.2 \approx 20 \langle \text{N m} \rangle$ ✓	Award [3] for a bald correct answer.	3
c	$\langle P = 45 \times 9.8 \times 2.0 \rangle = 882 \approx 880 \langle \text{W} \rangle$ ✓		1

Question		Answers	Notes	Total
7.	a	$\langle \text{maximum is at B and so } T_B = 400 \times \frac{8}{2} = \rangle 1600 \langle \text{K} \rangle \checkmark$		1
	b	$W = \langle p\Delta V = \rangle 5.0 \times 10^5 \times [8.0 - 2.0] \times 10^{-3} \checkmark$ $W = 3.0 \times 10^3 \langle \text{J} \rangle \checkmark$	<i>Award [2] for a bald correct answer.</i>	2
	b	$\Delta U = \langle \frac{3}{2} p\Delta V = \frac{3}{2} \times 3.0 \times 10^3 = \rangle 4.5 \times 10^3 \langle \text{J} \rangle \checkmark$	<i>Award [1] for a bald correct answer.</i>	1
	b	$Q = \langle \Delta U + W = 3.0 \times 10^3 + 4.5 \times 10^3 = \rangle 7.5 \times 10^3 \langle \text{J} \rangle \checkmark$	<i>Award [1] for a bald correct answer.</i>	1
	c	$\Delta S = \frac{Q}{T} = -\frac{1390}{400} \checkmark$ $\Delta S = -3.48 \approx -3.5 \langle \text{J K}^{-1} \rangle \checkmark$	<i>Award [1 max] for omitted minus sign.</i> <i>Award [2] for a bald correct answer.</i>	2
	d	$e = \frac{3000 - 1390}{7500} \checkmark$ $e = 0.21 \checkmark$	<i>Award [2] for a bald correct answer.</i>	2
	e	greater \checkmark		1

Option C — Imaging

Question		Answers	Notes	Total
8.	a	<p>the image would be formed at the focal point of the concave mirror OR at a distance of 9.50 m from the centre of the concave mirror <since the object distance is very large> ✓ $\langle - \rangle \frac{9.50}{u} = \frac{D_i}{D_o}$ ✓ $D_i = 9.50 \times \frac{D_o}{u} = 9.50 \times 1.40 \times 10^{-4}$ ✓ $= 0.00133 \langle \text{m} \rangle$</p>		3
	a	<p>the object distance is $-[9.50 - 8.57] = -0.93 \langle \text{m} \rangle$ ✓ so the magnification is $\frac{8.57}{0.93} = 9.215$ ✓ the diameter of this image is then $9.215 \times 0.00133 = 0.012256 \langle \text{m} \rangle$ ✓</p>	Ignore incorrect sign.	3
	a	<p>angle: $\frac{12.3 \langle \text{mm} \rangle}{98.0 \langle \text{mm} \rangle} = 0.126 \langle \text{rad} \rangle$ ✓ magnification: $\frac{0.126}{1.40 \times 10^{-4}}$ ✓ $= 900$ ✓</p>		3
	b	with parabolic mirrors the problem of spherical aberration is eliminated ✓		1

(continued...)

(Question 8 continued)

Question	Answers	Notes	Total
b ii	no chromatic aberration ✓ easier/cheaper to make large mirrors than large lenses ✓ easier to support and so can be large ✓ less absorption in glass ✓		1 max
c	a multitude of sources of EM radiation other than visible light have been discovered OR comparison of optical and non-optical images can be made ✓ thus vastly increasing our understanding of what exists in the universe ✓		2

9. a i	$\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{0.40 \times 10^{-2}} - \frac{1}{20 \times 10^{-2}} \quad \checkmark$		1
a ii	$M = \left(-\frac{v}{u} \times \frac{D}{f_e} \right) = \left(-\frac{0.20}{4.1 \times 10^{-3}} \times \frac{0.25}{3.2 \times 10^{-2}} \right) \quad \checkmark$ $M = 382.8 \approx 380 \quad \checkmark$		2
a iii	$\frac{0.1 \text{ (mm)}}{380} \approx 260 \text{ (nm)} \quad \checkmark$		1
b	attenuation = $(4.6 \times 6.2) = 28.5 \text{ (dB)} \quad \checkmark$ $p = 120 \times 10^{-2.85} \quad \checkmark$ power = $0.17 \text{ (mW)} \quad \checkmark$		3

Option D — Astrophysics

Question		Answers	Notes	Total
10.	a	helium ✓		1
	b	$d = \sqrt{\frac{3.8 \times 10^{27}}{4\pi \times 7.6 \times 10^{-14}}} \quad \checkmark$ $d = 6.3 \times 10^{19} \text{ m} \quad \checkmark$ $d = 2000 \text{ pc} \quad \checkmark$	Award [3] for a bald correct answer.	3
	b	no, the distance is too great for the parallax angle to be measured accurately <even from an orbiting telescope> ✓		1
	b	$\left[\frac{M}{M_{\odot}} \right]^{3.5} = 10 \quad \checkmark$ $\frac{M}{M_{\odot}} = 10^{\frac{1}{3.5}} = 1.93 \approx 2 \quad \checkmark$	Award [2] for a bald correct answer.	2
	c	estimates of temperatures for star as 7500 (±200) <K> and Sun as 6000 <K> ✓ $10 = \frac{\sigma 4\pi R^2 7500^4}{\sigma 4\pi R_{\odot}^2 6000^4} \quad \checkmark$ $\frac{R}{R_{\odot}} \approx 2 \quad \checkmark$	Accept answers in the range of 1.9 to 2.1.	3
	c	line starting at correct position [$T = 7500 \text{ K}$, $L = 10$] and extending into red giants ✓ ending at white dwarfs ✓		2

(continued...)

(Question 10 continued)

Question		Answers	Notes	Total
	c	equilibrium between gravitational pressure and electron degeneracy pressure ✓ provided final mass is below the Chandrasekhar limit/less than $1.4 M_{\odot}$ ✓		2
11.	i	the universe is expanding and so wavelengths \langle like all distances \rangle are being stretched out OR wavelength increasing hence the Doppler redshift is being observed ✓	<i>Must mention redshift in alternative answer.</i>	1
	ii	$\langle z = \frac{v}{c} \Rightarrow \rangle v = 0.157 \times 3.0 \times 10^8 = 4.7 \times 10^4 \langle \text{km s}^{-1} \rangle$ ✓ $d = \langle \frac{v}{H} = \frac{4.7 \times 10^4}{71} \Rightarrow \rangle 660 \langle \text{Mpc} \rangle$ ✓	<i>Award [2] for a bald correct answer.</i>	2
	i	gravity is pulling back on the galaxies ✓		1
	ii	distant supernovae appeared less bright than expected ✓ indicating that they were further away than expected ✓		2